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INFORMATION CIRCULAR

POSSIBLE HAZARDS ATTENDING THE USE OF ENGINES OPERATED ON BUTANE FUEL IN MINING AND TUNNELING

BY

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SSIBLE HAZARDS ATTENDING THE USE OF ENGINES OPERATED ON BUTANE FUEL IN MINING AND TUNNELING[1]

By L. B. Berger[2] and H. H. Schrenk[3]

INTRODUCTION

From time to time the Bureau of Mines receives requests for infor- ition and advice regarding the safety of using internal-combustion gines operated on butane fuel as prime movers for haulage and other rposes in mining and tunneling.

The purpose of this circular is to discuss the properties of butane d to present data in regard to the possible use of this fuel in underground erations.

Published information on the use of commercial butane as a fuel for ernal-combustion engines indicates that, insofar as performance is con- rned, butane may be utilized satisfactorily and efficiently for this purpose. wever, the introduction of a volatile, inflammable material such as butane o confined spaces such as mines or tunnels would create potential fire d explosion hazards that should be given due consideration by those con- rned with the promotion of safe practices.

A further consideration is that the combustion of any hydrocarbon in an internal-combustion engine may result in the discharge of con- erable quantities of the toxic gas, carbon monoxide, from the engine aust which can, and has, produced atmospheres decidedly dangerous to e in underground working places.

The Bureau of Mines always has advised against the use of gasoline gines underground because of the fire and explosion hazards attending

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the handling and use of the fuel, and because of the possibility of dangerou contamination of the air of working places by carbon monoxide from the engine exhaust. This opinion is expressed in Decision 19 of the Mine Safety Board of the Bureau of Mines[4] regarding the use of internal-combustion engines for mine haulage. The essential portions follow:

"In the interest of safety, the United States Bureau of Mines recommends that:

"1. Internal-combustion engines should not be used in any parts of mines and also should not be used in tunnels under construction because the hazard of carbon monoxide in the exhaust gases, except -

"(a) When the air current is more than 100 linear feet per minute and the toxic gases are always less than 0.02 percent in the air current.

"(b) When the inflammable gas in the air current is less than 0.25 percent and (or) inflammable gas cannot be detected in any place by a permissible flame safety lamp.

"2. Gasoline or other highly inflammable liquids should not be use for engine fuel in mines and in tunnels under construction because of the hazard of their transportation and use."

In addition to this decision by the Bureau of Mines, many State law or mining-department regulations[5] have forbidden the use of gasoline o other fuel-consuming engines in mines.

Subsequent discussion of the properties of butane fuel shows that it use in mining or tunneling operations may create potential hazards comparable to those attending the use of gasoline underground.

PROPERTIES OF BUTANE FUEL

The fuel known commercially as "butane" usually consists of a mi ture of propane, normal butane, and isobutane, gases that are obtained in the processing of natural gas and petroleum. In this circular the term "butane" is used to refer to such a mixture. As all of these hydrocarbo gases at ordinary temperatures and pressures, butane fuel usually is plied liquefied under pressure in metal tanks. Properties of propane, mal butane, and isobutane that are pertinent to the present discussion given in table 1, which contains also, for comparative purposes, some perties of gasoline.

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[4] Mine Safety Board, Recommendations of the United States Bureau of Mines on Certain Questions of Safety as of October 1, 1936: Burea of Mines Inf. Circ. 6946, June 1937, 45pp.

[5] Ilsley, L. C. and Gleim, E. J., State Regulations Pertaining to the Us Internal-Combustion Engines in Coal and Metal Mines and in Tunn Bureau of Mines Inf. Circ. 7019, 1938, 8 pp.

DISCUSSION OF PROPERTIES OF BUTANE FUEL AND COMPARISON WITH PROPERTIES OF GASOLINE

As shown in table 1, there is some difference between certain proper- s of the principal hydrocarbons comprising butane fuel, and therefore the perties of the commercial product will vary to some extent depending on proportion of each hydrocarbon present in a particular fuel. There is, ever, enough similarity in the properties of propane, normal butane, and utane to draw definite conclusions in regard to their characteristics as taining to hazards that might be created by their use underground.

The data on vapor pressure given in table 1 show that at temperatures may exist underground, say 60° F., the constituents of butane fuel will gases unless confined under pressure, as the vapor pressures exceed 1 osphere (14.7 lb./sq. in. at sea level).

From the data on heat values of butane fuel and gasoline, it may be d that approximately the same weight of butane fuel or gasoline would e to be used underground to obtain a given quantity of power from a engine. (This assumes that over-all efficiency is the same for butane nes and gasoline engines; actually efficiency will vary for either type e, depending on design and adjustment of the engine.) On a liquid- me basis it may be noted that, because of the smaller weight per gallon, ater liquid volume of butane fuel would have to be used underground to e available a given quantity of heat energy.

In regard to the limits of inflammability of the gases comprising butane and of gasoline vapor, there is not enough difference between this char- ristic of the two fuels to warrant a belief that butane fuel presents a er fire and explosion hazard than gasoline because of the slight difference wer inflammable limits. In this connection it is pointed out that butane , being gaseous at ordinary temperatures and pressures, might create a and explosion hazard immediately if some of the fuel should be dis- rged accidentally into the air of underground workings, whereas liquid line spilled or leaking underground would have to evaporate before an mmable mixture would be formed with the surrounding air.

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TABLE 1. - Properties of hydrocarbons comprising "butane" fuel, and some properties of gasoline

Properties	Butane fuel			
	Propane	Normal butane	Isobutane	Gasoline
Chemical formula	C_3H_8	C_4H_{10}	C_4H_{10}	C_8H_{18}[1]
Boiling point, °F.[2]	-44	33	14	[3]
Specific gravity gas (Air = 1)[2]	1.55	2.14	2.08	[4]
Vapor pressure, absolute, lb./sq. in.[2]: 0°F.	38.7	7.7	10.7	[4]
10°F.	46	9.5	13	[4]
20°F.	54.5	11.5	16	[4]
30°F.	65	14	20	[4]
40°F.	76	17	24.5	[4]
50°F.	90	21	30	[4]
60°F.	107	25	35	[4]
100°F.	211	52	70	7.0 to 10.5[5]
Weight per gallon liquid, at 60°F., lb.	4.24[2]	4.85[2]	4.72[2]	6.2[6]
Heat value, B.t.u. per lb.	21,680[2]	21,330[2]	21,280[2]	21,000[6]
Inflammable limits of gas in air[7]				
Lower, percent by volume	2.4	1.85	1.8	1.3[6]
Upper, do.	9.5	8.4	8.4	7.0[6]
Volume of gas per lb., cu. ft. at 60°F., 30 in. mercury[8]	8.59	6.52	6.52	3.31
Volume of inflammable atmosphere formed (at lower limit) by mixture of one lb. hydrocarbon with air, cu. ft. at 60°F., 30 in. mercury[9]	358	352	362	255

[1] An approximation; gasoline is a mixture of hydrocarbons.

[2] Weaver, E. R., Propane, Butane and Related Fuels: Bureau of Standards Circ. C420, 1938, 21pp.

[3] Gasoline is a mixture of hydrocarbons, and therefore has a boiling range, rather than a boiling point. Boiling range varies with composition. [4] Varies with composition.

[5] Lane, E. C., Cooperative Fuel Research Motor-Gasoline Survey, Winter 1940-41: Bureau of Mines Rept. of Investigations 3576, 1941, 29 pp. [6] Average value; varies with composition

[7] Coward, H. F., and Jones, G. W., Limits of Inflammability of Gases and Vapors: Bureau of Mines Bull. 279, 1938 revision, 146 pp. [8] Calculated from molecular weight, or assumed molecular weight in case of gasoline. [9] Calculated from data on lower inflammable limits

by lower inflammable limits

The potential hazard of using butane fuel underground is illustrated ther by the last item in table 1, which shows that a given weight of tane fuel discharged into the atmosphere of an underground working would create approximately a 40 percent greater volume of inflammae mixture than would the same weight of gasoline.

PRODUCTION OF CARBON MONOXIDE IN THE COMBUSTION OF BUTANE FUEL

Production of carbon monoxide by an internal-combustion engine erated on butane or any hydrocarbon fuel depends upon the proportions air and fuel supplied to the engine by the carburetting device. If this xture of air and fuel does not contain enough oxygen for complete comstion, carbon monoxide and other products of incomplete combustion ll be present in the exhaust gases of the engine.

References to the use of engines operated on butane fuel have been ted which state that less carbon monoxide is produced with the butane gine than with the gasoline engine. While this may be true of engines refully adjusted and operated, it is emphasized that such operation is an inherent characteristic of engines operated on butane fuel. There little published information on the composition of the exhaust gases proced by butane engines, but such analyses as have come to the attention the Bureau of Mines have indicated a wide range in concentration of carmonoxide. In some instances the analyses have indicated essentially plete combustion with production of very small quantities of carbon noxide, whereas in other cases the exhaust has contained carbon monide in concentrations as high, or higher, than the average gasoline engine uces. Samples collected in 1943 from the exhaust of trucks powered tane engines and analyzed by the Bureau of Mines contained 8 to 11 cent carbon monoxide.

A further consideration in regard to the composition of the exhaust the butane engine is that, even though the carburetting device of the ine were adjusted to minimize production of carbon monoxide, toxic es of nitrogen might be formed in quantities that would cause signifit contamination of the air of underground working places. Although no ntitative data are available on production of oxides of nitrogen by ines operated on butane fuel, it seems reasonable to assume that such mpounds are present in the exhaust, as the exhausts of both gasoline and sel engines contain appreciable concentrations of oxides of nitrogen.

ZARD OF GAS IGNITIONS BY INTERNAL-COMBUSTION ENGINES

Although not peculiar to engines operated on butane, attention is dicted to the fact that any internal-combustion engine not equipped with

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effective flame arresters on the intake and exhaust systems, and explosi proof or nonarcing electrical equipment, may act as a source of ignition methane or other inflammable gases that may be liberated from the strat in underground workings. This fact is considered in item 1 (b) of Mine Safety Board Decision 19, previously cited.

SUMMARY

1. The use of internal-combustion engines operated on gasoline for underground haulage is advised against by the Bureau of Mines, and is forbidden by many State mining laws.

2. The hazards that may attend the use of internal-combustion engines operated on butane fuel in mining and tunneling are discussed, and the properties of butane fuel are compared with those of gasoline.

3. The potential fire and explosion hazard that might result from t escape of butane fuel into the air of underground working places is consid ed somewhat greater than that of gasoline because of the greater volatilit of butane fuel and the fact that a given weight of this fuel will create a lar volume of inflammable gas-air mixture than will the same weight of gaso

4. While it may be possible to operate butane engines with produc of little carbon monoxide, such operation is not an inherent characteristi of butane engines, and can be realized only by careful adjustment of the engines. Some samples of butane engine exhaust gas analyzed by the Bur of Mines have contained carbon monoxide in concentrations equal to, or possibly greater than, those produced by the average gasoline engine.

5. Even though a butane engine was adjusted and operated in a ma that minimized production of carbon monoxide, the exhaust might contain oxides of nitrogen in sufficient quantity to cause significant contaminatio of the air of underground working places.

6. Any type of internal-combustion engine not fitted with suitable tective devices may be a potential source of fires or of ignition of infla ble gas liberated from the strata in underground workings.

CONCLUSION

The use of internal-combustion engines operated on butane fuel in underground operations such as mining or tunneling is not considered a safe practice by the Bureau of Mines.